Resort bungalows — poles supporting suspended floor and open gable roof

Materials

Poles

Stress Grade

Nature compensates for injuries and knots in a tree by shaping the fibres around these defects so that they are of little structural consequence. When the wood is sawn the inbuilt growing stresses and these internal defects become significant and the permissible stresses in the milled timber are reduced to about 50% of that of the log. Therefore pole elements are one of the best ways to utilise timber, saving both on wastage and milling cost. Balancing this, is the fact that logs are the way nature grew them, and it is difficult to build structures with components that taper, are oval and may be crooked. Poles can be prepared in a variety of ways for structural use and AS 2209 TIMBER POLES FOR OVERHEAD LINES (Ref 18) describes the permissible visual defects that correlate with the allowable design stresses. Refer Table 1 for species strength grouping and joint strength.

An airy and inviting entrance created with exposed hardwood poles

TABLE 1 POLE SPECIES AND STRENGTHS

Common Species	Pole Strength Group	Joint Strength Group
Mixed Hardwood	S4	J3
slash pine	S5	JD3
Radiata pine	S6	JD4

NOTE: 1. Reference should be made to AS 1720, SAA TIMBER STRUCTURES CODE, Section 6 for stress grades and permissible stresses.
2. For information on local availability of building poles, reference should be made to the Timber Advisory Services in each State.

AS 2209, describes acceptable limits for roundness and straightness, the size of knots, allowable checks and end splits. Since this Standard has wide application, there are several areas where the designer has to choose limits for appearance and durability, such as checks and splits.

Durability and Preservation

For poles in ground contact, only timber of Durability Class 1 should be used or poles containing sapwood that can effectively be pressure preservative treated to a H5 level as described in AS 1604, (Ref 13) AS 2209, (Ref 18) or the requirements of the Queensland Timber Utilisation and Marketing Act (1987) (TUMA) or the New South Wales Timber Marketing (Amendment) Act (1986) (TMA) whichever is appropriate.

NOTE: In Queensland and New South Wales the abovementioned regulations require timber poles sold as preservative treated to be branded in a prescribed manner which identifies the producer (treating plant) and indicates the type and level of treatment.

For poles mounted on stirrups or stools which lift them clear of ground contact, less durable species say Durability Class 2, or a H3 level of preservative treatment may be acceptable when used in an exposed situation. When used in a protected situation, any Durability class of timber can be used, provided any lyctid susceptible sapwood is treated to a H1 level in accordance with AS 1604.

NOTE: The sapwood of certain hardwood species is susceptible to attack by lyctids (lyctus borer). In these species, the sapwood should either be removed or treated to the appropriate level. Species which are not susceptible to lyctus borer are listed in the regulations of the Queensland TUMA 1987 and the New South Wales TMA 1986. A list of comparative susceptibility is available from the State Forest Services.

In summary, the following timbers are recommended:

Poles in ground —
- De-sapped Durability Class 1.
- Durability Class 1 with sapwood treated to H5 level.
- Plantation Softwood treated to a H5 level.

Poles on base plates — (Exposed)
- De-sapped Durability Class 2 or better.
- Durability Class 2 or better with sapwood treated to H3 level.
- Plantation Softwood treated to H3 level.

Poles on base plates — (Protected)
- Species of any Durability Class but with any lyctid susceptible sapwood treated to a H1 level.

NOTES:
1. Some sapwoods are not treatable and therefore cannot be made more durable.
2. Exposed poles are those subject to regular wetting due to rain.
3. Protected poles are those protected by the building fabric but may receive occasional wetting.

The preservative treatment most commonly used is CCA (Copper Chrome Arsenate) that produces a characteristic green colour. Since the replacement of a pole caused by decay would be difficult (especially with pole frame), then appropriate quality control should be demanded to ensure adequate treatment. Samples of critical areas of the pole should be checked for the retention of CCA. Independent checks can be arranged through the preservative treatment suppliers or the State Forest Services.

The specifier should require that the pole supplier both brand and certify the quality of the pole and its treatment.

Softwood Poles (Pine)

Pine poles readily accept treatment, are lighter and have a proven history of use in pole structures. The logs are mechanically debarked, and often shaved, to produce a pole of more uniform shape. This shaving can produce a circular or multi-faceted profile, but will reduce the strength of the timber. Small diameter pines (less than 225 mm diameter) are composed of less dense wood which correlates with less strength. Allowance should be made for this by reducing the permissible stresses and stiffness as specified in AS 1720 (Ref 15).

An industry practice has evolved which sizes poles based on Small End Diameters — SED. The poles are marketed in size ranges e.g. 200-225 mm. For design purposes the least size should be regarded as the diameter for strength design. When considering pole stiffness it may be more economic to be less conservative taking the average diameter with some additional allowance for taper since potted piles are always installed butt (large end) down.

Treated pine poles form the main structure of this home — walls set inside line of poles

Hardwood Poles

To extend the life of hardwood poles embedded in the ground, double treated poles may be used or additional maintenance near the ground can be applied. This maintenance would include flooding with creosote and diffusion chemicals such as Koppers CN Oil Emulsion.

A polythene tube can be embedded in the backfill to facilitate this. End splitting can be controlled by the use of end sealers such as wax emulsions and petroleum jelly, used together with nailplates or metal collars.

Pole Shape

The bow in a pole is called sweep and is defined in AS 2209. An acceptable single sweep in a pole 10 m long is 70 mm for a select grade pole. This, together with some non-circularity and taper, compounded by placement tolerances for both position and verticality, means that it is unlikely that the pole is in an accurate position at each level.

This does present some difficulties where the poles and walls are in-line. Figure 11 illustrates some methods of jointing to overcome these difficulties.

A solution is to place the poles inside or outside the external walls. In these cases, the poles should be at least 200 mm clear of the wall. This allows sufficient tolerance to build the structure using normal building practice.

Where the poles are incorporated into the wall then the following points will minimise difficulties in construction:

- use pinned bases as this allows plumbing of the poles to achieve the best alignment. Alternatively place poles in concrete pipes that are backfilled initially outside the pipe and then plumb the poles as the frame is constructed. Finally backfill between the pole and the pipe. Refer Figure 6. In good foundation conditions, concrete pipes may not be necessary.

- minimise the number of floors — the critical points that need to be aligned.

- use larger diameter poles as this masks the sweep (bow).

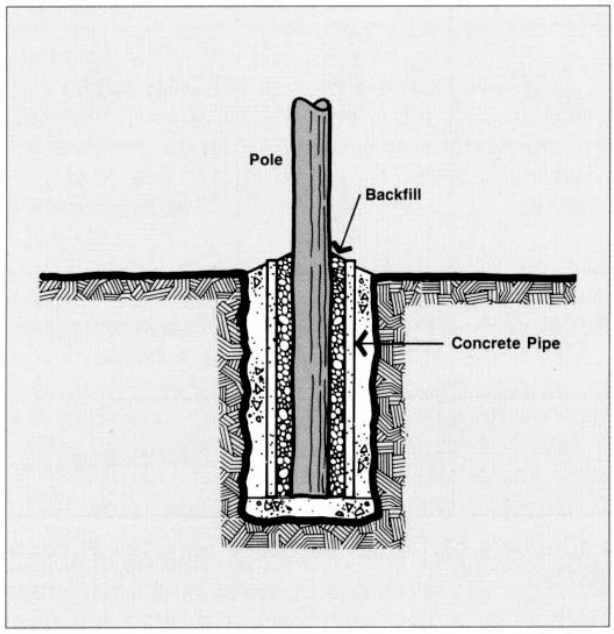


FIGURE 6 EMBEDDED POLE IN PIPE

Pole Protection

If the end of the pole is exposed to the weather, then a metal cap should be provided to prevent moisture entry and rapid end drying. Refer Figure 7.

Aluminium caps are suitable provided that the poles are at least 6 weeks old so that galvanic corrosion is minimised. Once the poles are on site it is important that the pole is not allowed to dry out too quickly otherwise surface checks will open. Apart from being unsightly, they provide a path to the inner, often untreated timber.

This can be reduced by standing the poles as quickly as possible, as the effects of the sun are more continuous if they are left lying down. Also coating with a water repellent or applying a painting system will slow the loss of water resulting in less surface distress.

Where cuts are made in the poles, untreated timber may be exposed and this could hasten decay if it is in an in-ground or exposed situation.

Accordingly, cutting and notching is not recommended in the embedded zone or to about 300 mm above the ground where moisture begins to reduce. All bearer and bracing fixings should be above this level. All cuts and drillings in areas exposed to the weather should have a preservative such as copper naphthenate emulsion applied to the fresh cut surfaces before assembling the joint.

The copper in CCA is responsible for an electrochemical corrosion that can be active in the first few months after treatment. Metals far removed from copper on the electrochemical scale will corrode if moisture is present. This means that iron, galvanising and aluminium will all be attacked.

All fastenings into CCA treated timber should be hot dipped galvanised, NOT zinc plated. Critical elements such as bolts should be well greased before installation in treated timber in protected areas. In the exposed situations and near the ground, the bolt shank should be provided with a shrink-on plastic sleeve or painted with a tar epoxy.

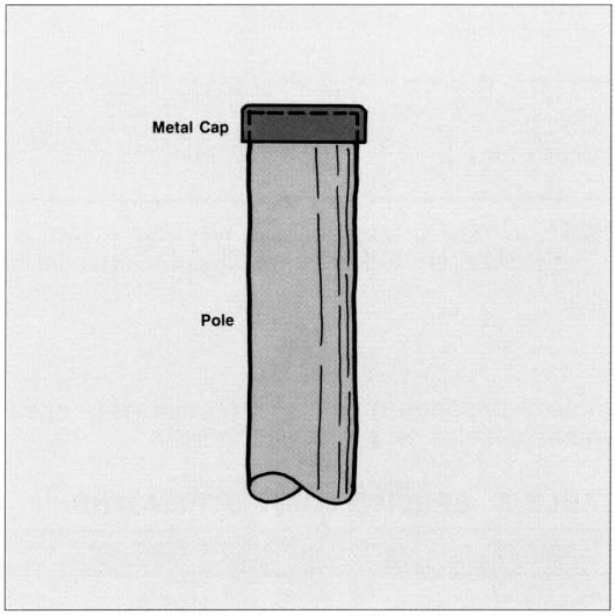


FIGURE 7 POLE CAP

Sawn Framing

All sawn structural timber should comply with the relevant Australian Standard. Table 2 provides information relevant to Australian Standards, stress grades and quality assurance programmes.

For framing in weather exposed situations, the natural durability or preservative treatment level should be appropriate to the application. Refer Datafile P4, TIMBER — DESIGN FOR DURABILITY.

TABLE 2 SAWN FRAMING

Species	Australian Standard	Stress Grades (Readily Available)	Quality Assurance Programme	Certification Brand	Availability (States)
Hardwood — Unseasoned	AS 2082	F8 to F17	AHQC	AHQC	All States (except WA)
			FPA (WA)	FPA	WA
Hardwood — Seasoned	AS 2082	F14 to F22	AHQC	AHQC	All States (except WA)
			FPA (WA)	FPA	WA
Softwood — Seasoned	AS 2858	F5, F8, F11	Pine Div QTB		Qld NSW
Radiata pine — Seasoned	AS 2858 AS 1748—1749	F5, F8, F11	RPAA	QC	All States
Cypress — unseasoned	AS 2858	F5	Cypress Div QTB	Cypress	Qld Vic NSW
Douglas fir — unseasoned	AS 2858	F7, F8	—	—	All States

NOTE: Not all grades will be available Australia wide and suppliers or Timber Advisory Services in each State should be consulted for specific local availability.

Table 3 provides guidance on commonly used timber species and joint strengths.

TABLE 3 SPECIES JOINT STRENGTHS

Species	Joint Strength
Mixed Hardwood	J3
Slash pine	JD3
Radiata pine	JD4
Oregon (Douglas fir)	J4
Cypress pine	J3

NOTE: For a more comprehensive schedule of species joint strengths, refer to Datafile P1, TIMBER SPECIES AND PROPERTIES.

Structural Design and Detailing

Embedded Poles

When the pole is surrounded by an unyielding backfill, the structure may be designed with base fixity and a consequent reduction in bracing elements. The embedment depth required for development of significant moment would range from 1.5 m to 2.4 m. The backfill must be easily compactable down the side of the pole in a space nominally 100 mm wide and up to 2.4 m deep. Suitable materials for backfilling would include gap-graded fine crushed rock or river gravel with 10 mm maximum aggregate size. For hardwood poles, a no-fines (10 mm maximum aggregate) concrete should provide structural support while allowing drainage of moisture away from the pole.

For these three systems, (Refer Figure 8), an impervious plug of clay or pre-mixed asphalt should be placed at the top to prevent surface water infiltration. Gravel is used to remove moisture from around the pole and dissipate it into the soil. If a water table is present then this may be counter productive, but in those circumstances, a driven pile is the preferred option since a bored hole would collapse during construction. Gravel and no-fines concrete are not useful backfills in soft clays as the soil particles may squeeze through the voids allowing base movement.

Ordinary concrete is an alternative backfill but is suitable only for use with treated pine poles. If the pole shrinks away from the concrete, fixity may be restored by pouring dry sand down the crevice. The crack can then be sealed using a bead of silicon based sealant. In the gravel backfilled poles, the effective width of the backfill pushing into the soil is usually about 80% of the hole diameter, while the concrete based backfills are fully effective in distributing the load over the full diameter. That is, the effective width of the laterally loaded pile, as far as the geomechanics design only is concerned, is 80% and 100% of the hole diameter respectively.

The vertical load on the pole foundations are concentrated due to the large grid and the often multi-storey nature of the building. For this reason it is imperative that a Geotechnical Engineer is engaged to investigate the proposed foundation soil. Details of concrete footings and timber sole plates are given in the AS 1684, SAA TIMBER FRAMING CODE (Table 2 Ref 14) for single floor loadings. In foundations of stiff clay or better, a no-fines concrete plug 200 mm deep should suffice to spread the load to limit settlement and, at the same time, allow dissipation of any moisture from the pole. It is important that all disturbed material is removed from the hole. Failure to remove loose soil can often result in severe differential settlements. Diversion of all surface water away from the poles is a worthwhile practice and this includes landscaping considerations and the siting of sprinklers etc.

Regular inspection for signs of distress should be conducted and provision should be made to pour creosote or other preservatives down any shrinkage crevices as they develop. These gaps should then be sealed with a gap filling caulking material. For improved long term performance or where the hazard is abnormally high, additional treatments, such as higher preservative loadings, double treatment and impregnated bandage wraps may be used.

The design of an embedded pile subjected to a lateral load has been a topic that continues to evolve. On the conservative side is Broms method that is prescribed in AS 2159, SAA PILING CODE (Ref 17), while some extremists use the old Rutledge Charts (Ref 1) that allow more movement.

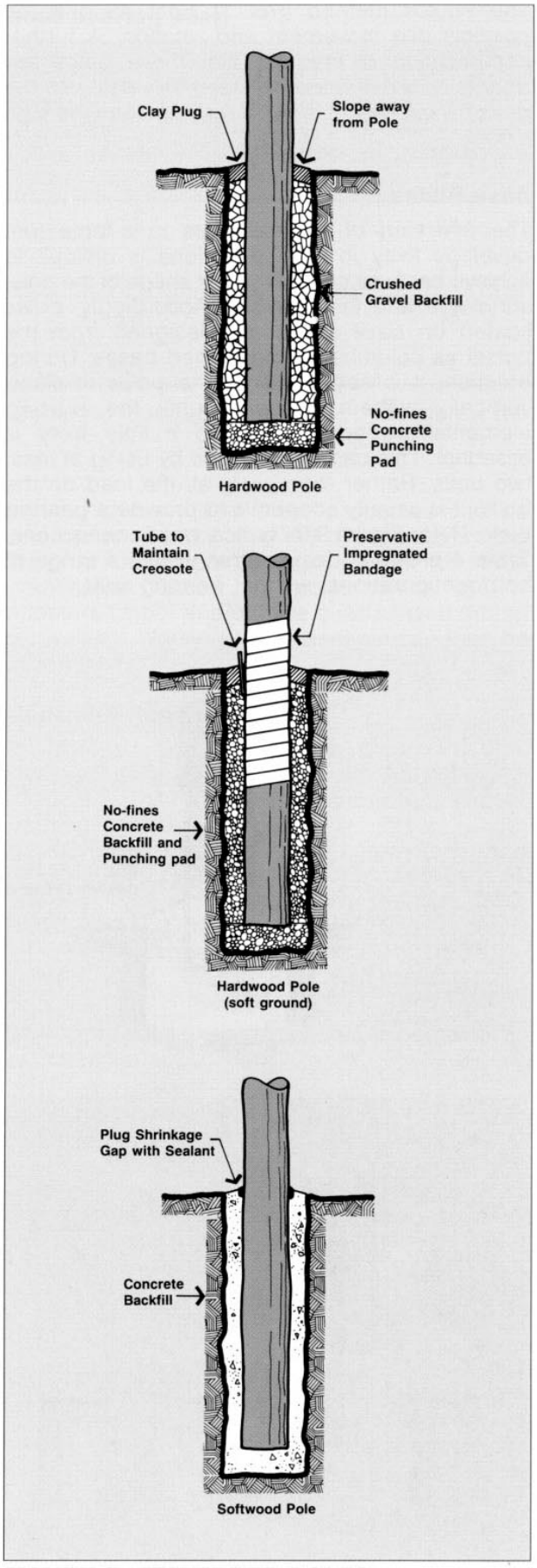
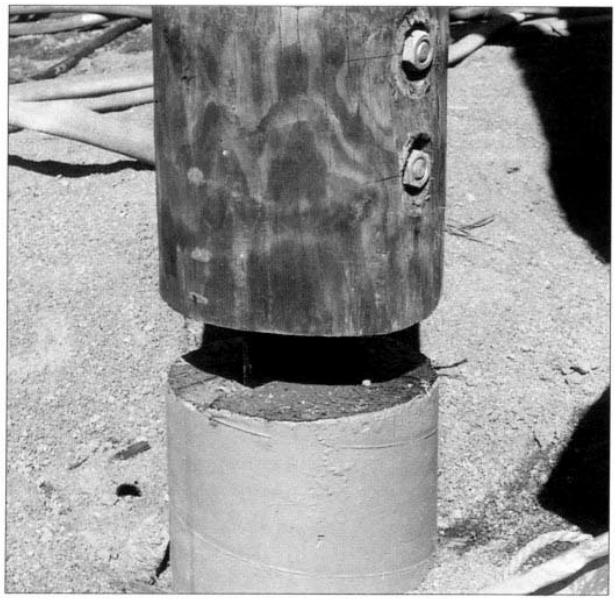


FIGURE 8 EMBEDDED POLES

The Poulos method (Ref 17 Sect A5 and 19) predicts pile movement and rotation. A further complication is the fact that these poles are generally constructed on steep hillsides with the downhill offering much less restraint than the high side.

Base Plates

The marrying of a base plate to a pole that develops fixity in both directions is difficult to achieve because of the irregular shape of the pole, shrinkage and fastener slip. Accordingly, poles seated on base plates are designed from the outset as columns having pinned bases. During erection, it is necessary for the poles to stand vertically without propping until the bracing elements are added and so a little fixity is essential. This can be provided by using at least two bolts. Rather than carry all the load on the bolts, it is usually economic to provide a bearing plate. Refer Figure 9 for typical base connections. Table 4 provides design strengths of a range of bolt configurations, without bearing seat.



Concealed base connection offers a neat and unobtrusive appearance

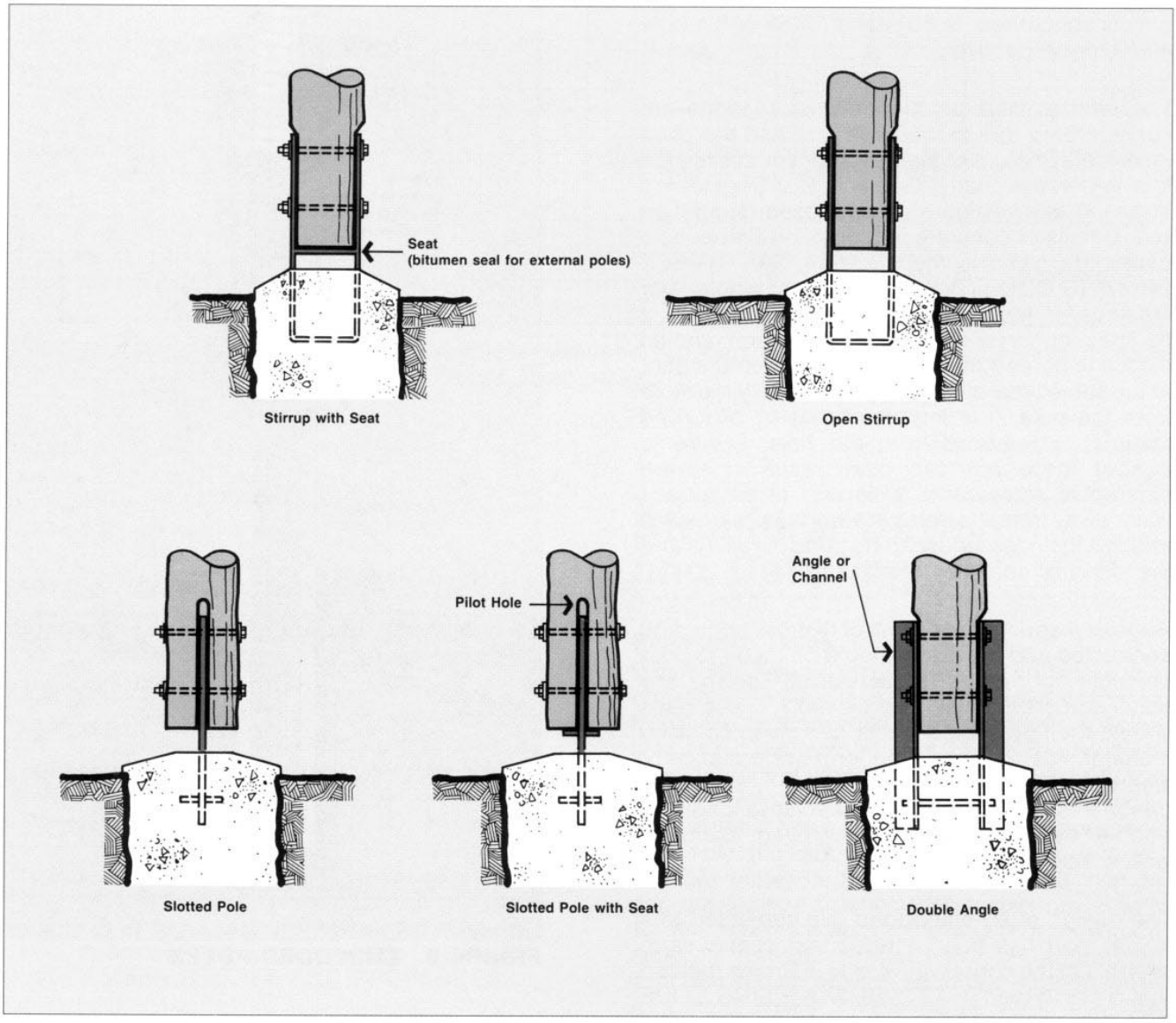


FIGURE 9 TYPICAL BASE CONNECTIONS

TABLE 4 CAPACITY OF OPEN STEEL STIRRUP (without bearing seat)

Pole Joint Group	Bolt Sizes					
	2/M16		2/M20		2/M24	
	Strength kN	Area m²	Strength kN	Area m²	Strength kN	Area m²
J1	28	11.2	44	17.6	63	25
J2	23	9.2	36	14.4	52	21
J3	22	9	34	13.6	48	19
J4	17	7	26	10.4	38	15

NOTE: "AREA" = maximum floor area supported under domestic loadings. For two or three-storey, the floor areas at each storey should be added.

Poles

The design of the poles can be considered in a number of ways, depending on the type of fixity achieved at the base. For embedded poles, enough fixity can usually be generated to design the poles as inter-connected cantilevers, with varying degrees of indeterminacy, dependant on the floor arrangement and inter-connection of poles.

Where the poles incorporate pin bases, no design is the same as for any braced structure. In these cases, relatively small diameter poles can usually be made to work; however, for architectural reasons, it is wiser to choose a larger pole diameter, more in keeping with the scale of the structure.

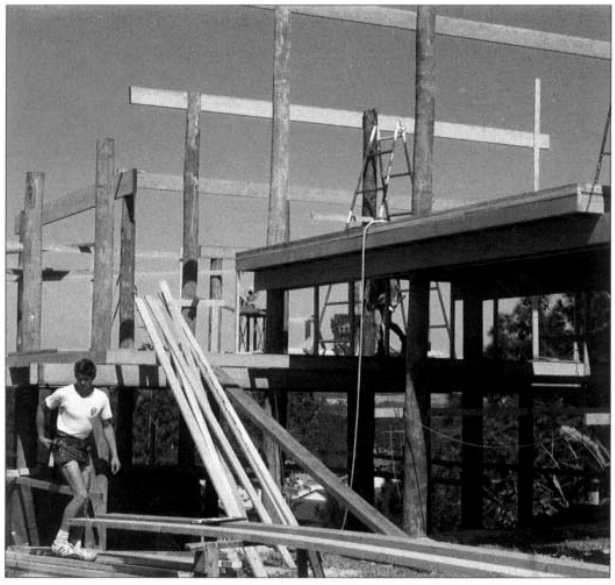
The strength group of the pole to be used will dictate the stress grade of the poles in accordance with Table 6.1 of AS 1720.1. By reading directly from Table 2.3 and 2.4 of AS 1720.1, the other working stresses and other properties can be determined. Section 6 of AS 1720.1, covers the design of round timber and gives additional stress modification factors for poles which are of immature timber and/or have been shaved during processing. Working stress analysis can then be undertaken.

Mechanically boring of holes — speedy and efficient

Floor and Roof Framing

For domestic load conditions, sawn structural framing shall be in accordance with AS 1684, SAA TIMBER FRAMING CODE or appropriate Timber Framing Manuals prepared by State Timber Industry Organisations. For commercial and industrial flooring and decking applications, reference should be made to Datafiles SS3, TIMBER FLOORS — COMMERCIAL AND INDUSTRIAL and SS4, TIMBER DECKS— COMMERCIAL, INDUSTRIAL AND MARINE.

Table 5 provides examples of double bearer sizes for domestic applications.



Erection of floors is quick and easy and provides safe working conditions

TABLE 5 DOUBLE BEARERS FOR DOMESTIC APPLICATIONS

Bearer Span (m)	Bearer Spacing (m)	Bearer Size (mm x mm)					
		Unseasoned			Seasoned		
		F8	F11	F17	F8	F14	F22
2.7	2.7	2/150 x 50	2/150 x 50	2/125 x 50	2/140 x 45	2/120 x 45	2/120 x 45
		2/150 x 75	2/125 x 75	2/125 x 75	2/140 x 70	2/120 x 70	2/120 x 70
3.0	3.0	2/175 x 50	2/175 x 50	2/150 x 50	2/190 x 45	2/140 x 45	2/140 x 45
		2/150 x 75	2/150 x 75	2/125 x 75	2/170 x 70	2/140 x 70	2/120 x 70
	3.6	2/200 x 50	2/150 x 50	2/150 x 50	2/220 x 45	2/170 x 45	2/140 x 45
		2/175 x 75	2/150 x 75	2/150 x 75	2/170 x 70	2/140 x 70	2/140 x 70
3.6	3.6	2/250 x 50	2/225 x 50	2/175 x 50	2/240 x 45	2/190 x 45	2/170 x 45
		2/200 x 75	2/175 x 75	2/175 x 75	2/220 x 70	2/170 x 70	2/170 x 70
	4.2	2/250 x 50	2/250 x 50	2/200 x 50	2/290 x 45	2/220 x 45	2/190 x 45
		2/225 x 75	2/225 x 75	2/175 x 75	2/220 x 70	2/190 x 70	2/170 x 70
4.2	3.6	—	2/300 x 50*	2/275 x 50*	—	—	2/240 x 45*
		2/300 x 75*	2/275 x 75*	2/250 x 75*	—	2/240 x 70*	2/240 x 70*
	4.2	—	2/350 x 50*	2/300 x 50*	—	—	—
		2/325 x 75*	2/300 x 75*	2/275 x 75*	—	—	—

NOTE: All members in the above table are two span continuous except those marked *.

The use of a grid allows accurate setting out, especially on difficult terrain and more effectively locates the framing members to resist lateral sway. The use of continuous members, wherever possible, produces a stiffer structure and the fewer splices makes construction much simpler. If the grid chosen is non-uniform and the floor framing is unseasoned then the one depth of member (to suit the largest span/spacing) should be used over the whole structure to simplify construction and to reduce differential timber shrinkage.

Bearers can be used in pairs to minimise connection loads and the resulting smaller sections makes them easier to lift. Refer Figure 10. It is common to use 45 or 50 mm wide double bearers, but these should be restrained by solid blocking between each pair at the third points and some care may need to be taken in exposed locations to prevent cupping.

Large cantilevers may be supported by knee braces. Refer Figure 11.

In order to provide support to flooring and to maintain a rigid structure joists should be placed both sides of the pole. This provides a load path that enables forces in the floor diaphragm to pass via these joists into the bearers and then into the poles, while at the same time accommodating shrinkage. The flooring should not be cut into the pole and floor joists should not be fixed directly to the pole.

Some typical details of roof construction are illustrated in Figure 12.

The use of roundwood as building elements, other than as columns, requires a degree of commitment from the carpenter and designer alike. This is because it is difficult to marry one round shape to another. The constant fitting of the joint as fabrication proceeds is usually not practical given the difficulty of the site and the weight of these components.

Inter-connecting poles require attention to joint detail